October Program Highlights

Integrating Enhanced GRACE Water Storage Data into the U.S. and North American Drought Monitors

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Highlight: The 1st maps of soil and aquifer wetness conditions with the resolution and timeliness necessary for operational drought monitoring (Figure 1) were created, by synthesizing GRACE with other observations within a sophisticated numerical model of land surface water and energy processes. Scientists at NASA/GSFC, NOAA, the National Drought Mitigation Center, and UC Irvine teamed up to develop these new drought indicator maps based on satellite observations from NASA's GRACE and other missions. GRACE provides information on the total amount of water stored at all levels on and below the land surface, including surface waters, snow, soil moisture, and groundwater, making it an obvious candidate for remote sensing of drought.

The maps are available from http://www.drought.unl.edu/MonitoringTools.aspx

Relevance: The U.S. and North American Drought Monitors are the premier decision support tools for drought monitoring. Previously, the Drought Monitor authors lacked information on groundwater storage conditions and had very little objective information on soil moisture, two key indicators of drought. Through this project, those two information gaps have been filled, and the Drought Monitor authors are now testing our results as inputs to their products.

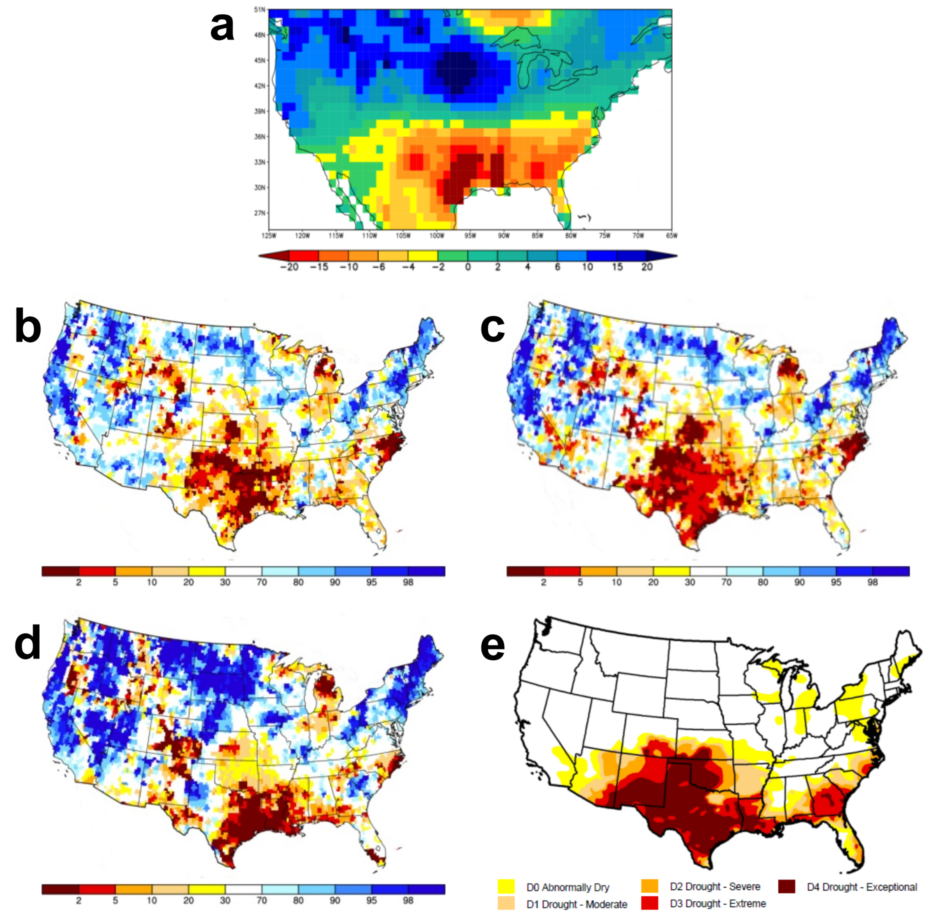

Figure 1. (a) GRACE terrestrial water storage anomalies (cm equivalent height of water) for July 2011; (b-d) surface soil moisture, root zone soil moisture, and groundwater drought indicators from GRACE data assimilation (wetness percentiles relative to the period 1948-present) for 25 July 2011; (e) U.S. Drought Monitor product for 26 July 2011.

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Project Summary: The goal of this project is to integrate terrestrial water storage data derived from NASA's Gravity Recovery and Climate Experiment (GRACE) satellites into the U.S. and North American Drought Monitors, two of the premier drought products used by governments and stakeholders to assess and minimize drought impacts.

Earth Science Products: This project makes use of terrestrial water storage change data from the GRACE mission, which are synthesized with several other satellite derived products, including merged precipitation data and satellite based solar radiation data, within a high resolution land surface modeling and data assimilation system.

Technical Description of the Images: GRACE terrestrial water storage anomalies (a) for July 2011 were integrated with other data within a numerical land surface model. The resulting groundwater and surface and root zone soil moisture fields were then converted to wetness percentiles relative to a 1948-present simulation by the same model. Panels b-d show the results for 25 July 2011, which generally are consistent with the U.S. Drought Monitor product for 26 July 2011 (e) and also contain information on the part of the soil column being impacted by drought.

Application to Decision Making: Currently, the Drought Monitors rely heavily on precipitation indices and subjective reports and lack objective information on soil moisture and groundwater storage conditions. GRACE routinely maps Earth's gravity field with enough precision to infer changes in water stored below the surface, including groundwater. Thus GRACE has great potential to improve the Drought Monitors by filling that observational gap. The value of the GRACE data can be further enhanced through data assimilation, which synthesizes the advantages of observations and numerical land surface models, enabling spatial and temporal downscaling and vertical decomposition of GRACE derived terrestrial water storage into groundwater, soil moisture, and snow. Resulting GRACE data assimilation based drought indicators are now being tested as inputs to the Drought Monitors by our partners at NOAA and the National Drought Mitigation Center. We expect this will lead to more accurate drought assessments, ultimately benefitting the many stakeholders who depend on these products.

Scientific Heritage: In addition to the capability to derive information useful for hydrology from satellite gravimetry observations, which was developed and improved by geodesists beginning with Wahr et al. (1998), GRACE data assimilation (Zaitchik et al., 2008) was the major breakthrough that enabled GRACE based hydrology observations to be downscaled and vertically disaggregated, thus providing the timeliness, resolution, and specificity needed for drought monitoring.

References:

Houborg, R., M. Rodell, B. Li, R. Reichle, and B. Zaitchik, Drought indicators based on model assimilated GRACE terrestrial water storage observations, Wat. Resour. Res., submitted, 2011.

Wahr, J., M. Molenaar, and F. Bryan, 1998: Time-variability of the Earth's gravity field: hydrological and oceanic effects and their possible detection using GRACE. J. Geophys. Res., 103(B12), 30,205-30,230.

Zaitchik, B.F., M. Rodell, and R.H. Reichle, Assimilation of GRACE terrestrial water storage data into a land surface model: results for the Mississippi River Basin, J. Hydrometeor., 9 (3), 535-548, doi:10.1175/2007JHM951.1, 2008.

Satellite Data Comparison improves Web Service for Atmospheric Model Evaluation

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Highlight: User defined improvements were made to online analysis tool featuring the Linux-based Atmospheric Model Evaluation Tool (AMET). AMET has been widely used to evaluate the Community Multistage Air Quality (CMAQ) model performance against ground-based observations . AMET Version 2 extends these capabilities to *statistical* comparisons of CMAQ column-integrated data against those from satellites, e.g., Aerosol Optical Depth and NO_2 column, as well as from other models. This is useful for both research and air quality planning, providing a better understanding of aloft processes such as trans-boundary transport, and how well they are represented in models. AMET2 (beta) is implemented in the Visibility Information Web System (VIEWS) as an analysis web service and is being tested by system end users.

Relevance: State-level air quality (AQ) managers are required to use U.S. EPA-approved and thoroughly evaluated models to develop plans demonstrating compliance with AQ regulations. Air quality models (AQMs) used in these state implementation plans (SIPs) are seldom examined for aloft performance due to the sparse measurements above ground. This project has allowed VIEWS to ingest important satellite-derived metrics for criteria pollutants to allow assessment of AQMs over all three spatial dimensions of the atmosphere. Typical AQMs used in SIPs have never been quantitatively compared against these metrics. The addition of AMET2 and supporting tools in VIEWS through this project considerably advances and facilitates the use new tools and metrics in AQ decision-support systems.

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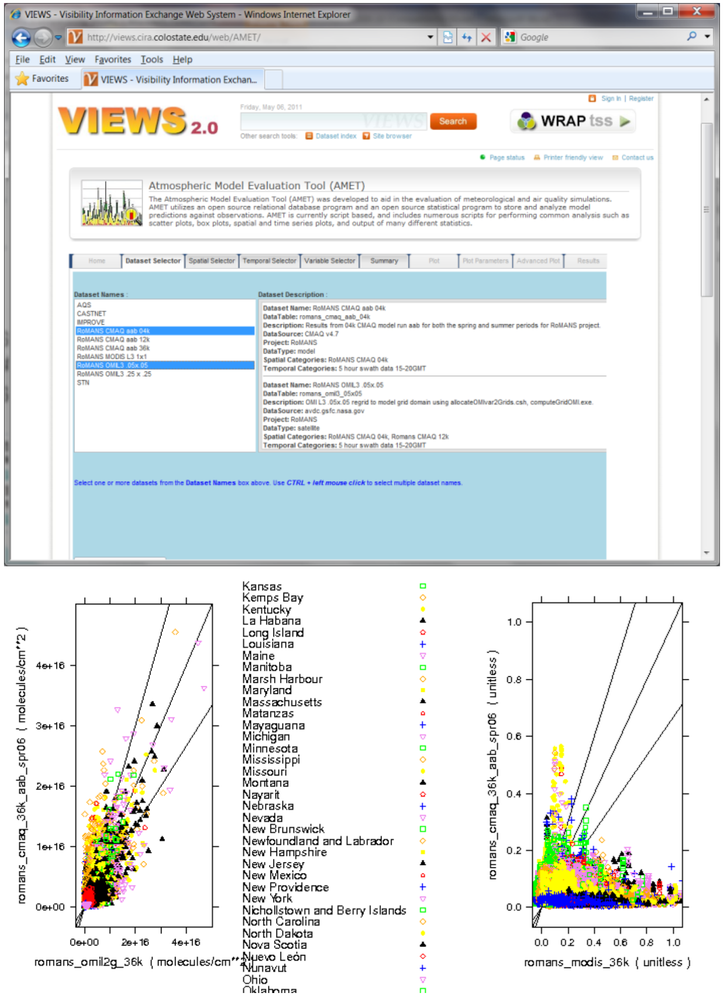

Figure 1: Top: VIEWS web page for AMET data selection; bottom: AMET scatter plots. L: CMAQ vs. OMI NO_2; R: CMAQ vs. MODIS (550 nm) AOD for a continental U.S. simulation at 36-km resolution in April 2006

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Project Summary: Visibility Information Exchange Web System-Technical Support System (VIEWS-TSS) integrates both ground- and space-based observations with 3-D emissions data and air quality modeling results. Along with advanced analysis tools, this provides multiple perspectives on the spatial distribution and temporal evolution of atmospheric pollutants, building a more complete body of information to support critical decisions on the control of the responsible pollutant sources.

Earth Science Products: As a use case, tropospheric NO_2 column from OMI, and aerosol products from OMI and MODIS are being used along with intensive field measurements for a diagnostic evaluation of the CMAQ model to understand the relative impacts of industrial and agricultural emission sources during the Rocky Mountain National Park Nitrogen and Sulfur (RoMANS) study. The NO_2 column is useful for analyzing both ozone and particulate nitrate chemistry and transport. As both CAMx and CMAQ models used in SIPs under predict total ammonium in RoMANS, TES NH_3 is also being used in consultation with the Aura Science Team to investigate model performance for NH_3.

Technical Description of the Images: The AMET web tool is implemented as a beta version in VIEWS and is launched from the VIEWS main page. The top panel shows the AMET data selection web page, including the metadata display for the datasets selected from the available data loaded in the AMET database. Once the modeled and observational data sets are selected, the user selects the desired time periods and spatial locations. The tool finds and reports how many model-obs data pairs were matched in these selections, and generates user-selected plots of the paired data from a menu of twenty statistical plot types. The bottom panel provides sample scatter plots of CMAQ vs. OMI NO_2 column and CMAQ vs. MODIS AOD at 550 nm.

Application to Decision Making: The quantitative analyses available through AMET are the staple of AQ model performance evaluations needed to develop State and Tribal Implementation Plans for meeting the National Ambient Air Quality Standards. The addition of new satellite-derived metrics to these analyses help better understand vertical mixing and long-range transport of pollutants. This can enable AQ managers to identify local vs. remote source contributions of pollutants such as nitrogen, which are reaching critical loads in sensitive ecosystems, and implement appropriate control measures for those sources within their jurisdiction.

Scientific Heritage: The OMI NO_2 column (Boersma et al., 2007) will be critical in evaluating CMAQ nitrogen predictions aloft. The CMAQ model is described in Byun and Schere (2006) and Binkowski and Roselle (2003). AMET2 builds upon the AMET1.1 development by the EPA Office of Research and Development.

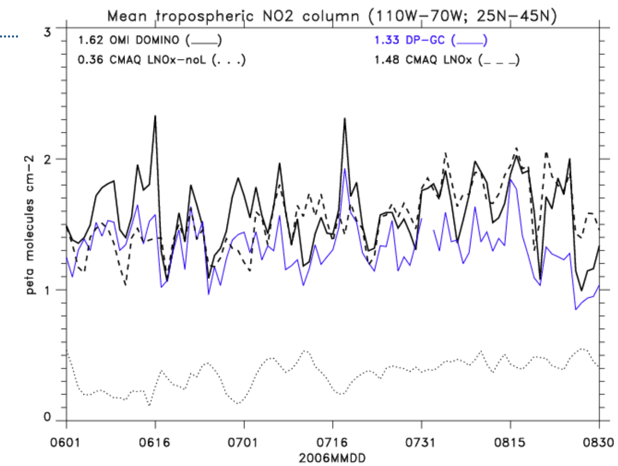
References: Boersma et al., *Atmos. Chem. Phys., 7*, 2103, 2007; Byun and Schere, *Appl. Mech. Rev., 59*, 51, 2006; Binkowski and Roselle, *JGR, 108*(D6), 4183, 2003; Rodriguez, et al., *Atmos. Environ., 45*, 223-234, 2011.

Implementation of a Lightning NO_x Emission Algorithm in the EPA CMAQ Model

Kenneth Pickering, GSFC

Highlight: An algorithm to produce estimates of NO_x emissions from lightning was developed for EPA's Community Multistage Air Quality (CMAQ) model. NO_x emissions from lightning account for up to 25% of the total column during the summer over the US. This algorithm is included in the latest version of CMAQ to be released by EPA in October 2011. The vertical distribution of the lightning NO_x emissions is based on the results of an Applied Sciences Feasibility Study (W. Koshak, PI). Without the lightning algorithm CMAQ NO_2 columns were biased low by 15-30% depending on satellite product. Comparisons with OMI version 2.0 DOMINO NO_2 data show that with inclusion of lightning, the model columns are within 5% of observations averaged over Summer 2006 over the US.

Relevance: The lightning-NO source was not previously included in CMAQ. With the resulting model column NO_2 having a substantial low bias, it was not possible to use inverse modeling techniques to constrain anthropogenic emissions or to determine the contribution of natural processes to nitrogen deposition. These activities are now possible with the CMAQ model. Inclusion of lightning adds 1.5 – 4.5 ppbv to maximum 8-hour average surface O_3 and increases wet deposition of oxidized nitrogen by 50%, bringing the mean bias with respect to National Atmospheric Deposition measurements to near zero.



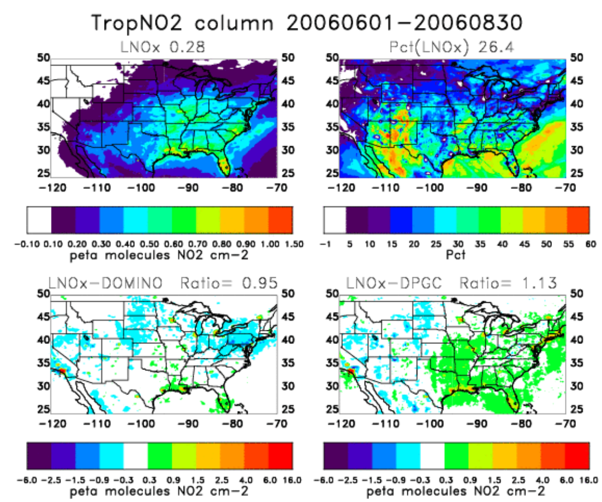


Figure 1: Time series of mean tropospheric column NO_2 from the CMAQ model and two versions of OMI retrievals over the given lat/lon range during Summer 2006. Figure 2: For summer 2006, clockwise from upper left: CMAQ tropospheric NO_2 due to lightning, percentage of column due to lightning, CMAQ minus OMI DP-GC, and CMAQ minus OMI DOMINO.

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Project Summary: Project Title: Monitoring Air Quality Effects of Anthropogenic Emission Reductions and Estimating Emissions from Natural Sources". This project consisted of three components: 1) implementation of a system for monitoring NO_2 air quality changes in regions affected by NO_x emission reductions at major point sources in the US using OMI NO_2 data; 2) preparation of a lightning NOx emission algorithm for use in EPA's CMAQ model and testing of the algorithm using OMI NO2 data; 3) use of OMI NO2 data in assessing the accuracy of the current soil NOx emission algorithm used for CMAQ.

Earth Science Products: OMI tropospheric NO2, OMI tropospheric O3, lightning NOx algorithm from NASA GMI model, results from analysis of Lightning Mapping Array data in feasibility study of W. Koshak (MSFC).

Technical Description of the Images: Figure 1: Time series of tropospheric NO2 columns for Summer 2006 averaged over the region 70-110 deg. W and 25 – 45 deg. N. Solid black (blue) line indicates columns from the DOMINO Version 2 product from KNMI (DP-GC product of Lamsal et al. (2010)). Dashed black line indicates columns from the CMAQ model including lightning NOx emissions. Dotted black line shows the column contribution from lightning. Figure 2: upper left plot: map showing lightning contribution to tropospheric column NO2 in CMAQ averaged over Summer 2006; upper right plot: percentage contribution to tropospheric column NO2 in CMAQ averaged over Summer 2006; lower left plot: bias in CMAQ tropospheric column NO2 compared with OMI DOMINO NO2 averaged over Summer 2006; lower right plot: bias in CMAQ tropospheric column NO2 compared with OMI DP-GC averaged over Summer 2006. Note average ratio of CMAQ to the OMI products are given on the lower two plots (0.95 for DOMINO and 1.13 for DP-GC).

Application to Decision Making: The lightning NOx algorithm is being included in the latest version of CMAQ due to be released in October 2011. Inclusion of this algorithm will allow CMAQ users (EPA, state and local air quality agencies, etc.) to better use assess NOx emissions in the model through use of satellite data. Resulting better emissions data will improve CMAQ estimates of ozone and the regulatory process.

Scientific Heritage: The lightning NOx algorithm (Allen et al., 2010) from the NASA GMI model was adapted and modified for use in CMAQ.

References:
Allen, D., K. Pickering, B. Duncan, and M. Damon (2010), Impact of lightning NO emissions on North American photochemistry as determined using the Global Modeling Initiative (GMI) model, *J. Geophys. Res.*, 115, D22301, doi: 10.1029/2010JD014062.

Allen, D., K. Pickering, R. Pinder, B. Henderson, K. Appel, and A. Prados, (2011) Impact of lightning-NO on eastern United States photochemistry during the summer of 2006 as determined using the CMAQ model, *Atmos. Chem. Phys.,* in revision.